Ref #23

412.32

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

INTERRELATION OF ABNORMALLY LOW TEMPERATURES AND SUBSEQUENT MORTALITY OF OVERWINTERING BROODS OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

by
James C. Evenden
Entomologist

Forest Insect Laboratory
Coeur d'Alene, Idaho
January 31, 1936

U. S. GOVERNMENT PRINTING OFFICE: 1923 J 76123

INTERRELATION OF ABNORMALLY LOW TEMPERATURES AND SUBSEQUENT MORTALITY OF OVERWINTERING BROODS OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

INTRODUCTION

The interrelation of extreme low temperatures and the mortality of overwintering broods of bark beetle larvae is recognized as a factor in the natural control of these insects. A number of instances are on record where heavy brood mortality occurred with the advent of such extreme conditions. Both field and laboratory studies relating to this association have been conducted at the forest insect laboratories of the Bureau of Entomology and Plant Quarantine. The results of some of these studies have been published and a number of unpublished reports have been prepared. This report presents the results of a small field project, instituted in February 1935 and completed the following June, which deals with the effect of low temperatures upon overwintering broods of the mountain pine beetle in lodgepole pine. The field work in connection with this project was conducted by Messrs. Gibson and Terrell of the Coeur d'Alene Laboratory.

DESCRIPTION OF THE PROJECT

The sudden, severe cold spell of January, 1935 presented an opportunity to secure additional information on the interrelation of abnormally low temperatures and the subsequent mortality of mountain pine

beetle broods in lodgepole pine. Material for subsequent laboratory examination was secured from the infested lodgepole pine areas to the west and south of Yellowstone Park. This material consisted of blocks of wood taken from the north and south sides of infested trees at the base and at a height of five feet. Data were taken relative to the elevation, exposure, character of timber stand, and diameter of trees sampled. Sample blocks were secured from 54 lodgepole pine, and 15 whitebark pine trees on seven different areas in Montana, Idaho, and Wyoming.

An open truck was used to transport this material to Coeur d'Alene so that it would not be subjected to any great change in temperature. Prior to being examined the blocks were kept in a cool, moist condition to prevent excessive desiccation. Temporary assistance was secured to expedite this work which was pushed as rapidly as possible in order to prevent the intervention of additional factors of mortality. Data secured from this examination were the size of the samples, total length of egg galleries, bark thickness, and the number of living and recently killed larvae.

Though it was not difficult to differentiate between the larvae assumed to have been killed by freezing and those which had been dead for some time, there were cases where it was very difficult to separate some of the recently killed ones from those which were merely dormant. All such border-line cases were referred to the Bureau officer supervising the examination.

TEMPERATURE DATA

In attempting to correlate the brood mortality data with the temperature records, it was evident that some method of evaluating the severity of the cold spell, which varied for the different areas, was necessary. In arriving at such an evaluation it was obvious that the point to which the maximum temperature fell each day was of far more importance than an extremely low minimum temperature associated with an above-zero maximum. There is no mortality in the broods of the mountain pine beetle until lethal temperatures exist beneath the bark. From studies conducted with controlled low-temperature equipment at the Berkeley Laboratory of this Bureau, it has been shown that a temperature of approximately -10 to -13 degrees are required to produce a 100 percent mortality of mountain pine beetle larvae from this region. To secure such lethal conditions, abnormally low maximum temperatures are necessary to overcome the lag which exists between the temperature beneath the bark and that of the air resulting from the insulating properties of the bark. As an example, a 24-hour period with a temperature of -20° minimum and -15° maximum would do far more in effecting such a condition than a -40° minimum and a zero maximum. With this temperature requirement in mind, the total number of continuous hours of temperature below zero, to which sum has been added the number of continuous hours of temperature below -10 degrees, plus those below -20 degrees, below -30 degrees, etc., has been used to provide a figure

showing a relative value of varying temperature records. Such an evaluation, though believed to be fundamentally sound, was developed without a basic foundation, as the relative weights adopted for the different temperatures below zero were but arbitrary selections. However, it offers a fair method of measuring the potential effect which cold spells will have upon overwintering broods of bark beetles. To secure the detailed data required in making this evaluation with only maximum and minimum temperature readings available, a hypothetical thermograph chart was constructed by assuming the minimum temperature to have occurred at 5 a.m. and the maximum temperature at 2 p.m.

Maximum and minimum temperature records were secured from the nearest Weather Bureau stations to the area where the samples were secured. The weakness of these data is recognized, for though they provided an accurate record of the temperatures at the stations, there was no assurance that they represented conditions at the place where the samples were secured. It is very evident that a distance of a few miles, with a change in exposure, topography, and especially elevation will often result in an entirely different set of temperature conditions from those recorded at the station. This possibility is definitely demonstrated by the difference which existed in the temperatures recorded at the different Weather Bureau stations within the rather small territory covered by this project. However, these records were used as offering the best data available.

The following tables present the data secured from the various areas sampled in their relationship to the allocated temperatures.

ASHTON, IDAHO

Temperatures at Bechler River Ranger Station

Date in January	18	19	20	21	22	23
Maximum Temperatures	20	24	6	9	20	31
Minimum Temperatures	15	0	-22	-32	3	10

Temperature records from the Bechler River Ranger Station, 17 miles southeast of the area sampled, were used as being the most representative available. The elevation of the Bechler Station is about 5,350 feet, while the area where the samples were secured, which is 12 miles north of Ashton, is approximately 6,600 feet.

Measurement of Existing Temperatures

Continuous hours of temperature below 0°F	20
Total number of above hours below -10°F	14
" " " " " " -20°F	8
" " " " " " -30°F	1
" " " " " " -40°F	0
Temperature measurement - - - - - - - - - - - -	43

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree			5' Above Ground			
Side of tree	Total brood per sq.ft.	Percent of mortality	Total brood per sq. ft.	Percent of mortality	Percent of mortality for different bark thicknesses	
					.10-20	.21-30 .31-40
N	69.7	2.2	71.3	9.3	9.8	2.1 --
S	48.1	5.0	92.8	5.9		

JACKSON HOLE, WYOMING

Temperatures at Moran, Wyoming

Date in January	19	20	21	22	23	24
Maximum	20	15	6	26	34	42
Minimum	5	-20	-40	-10	-4	11

The temperature records from Moran, Wyoming, 13 miles north of the area sampled, were used as being more representative of existing conditions than any others available. Elevation of the area sampled (Windy Point) was about 6,600 feet and that of Moran about 6,750 feet.

Measurement of Existing Temperatures

Continuous hours of temperature below	0°F	19
Total number of above hours below	-10°F	14
" " " " " "	-20°F	9
" " " " " "	-30°F	5
" " " " " "	-40°F	0
Temperature measurement - - - - - - - - - - - - -		47

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree			5' Above Ground		
Side of tree	Total brood per sq. ft.	Percent of mortality	Total brood per sq.ft.	Percent of mortality	Percent of mortality for different bark thicknesses
					.10-20: .21-30: .31-40
N	129.2	53.8	99.8	16.6	10.9: 22.5 :
S	61.8	22.3	107.0	10.0	

WISE RIVER, MONTANA

Temperatures at Wisdom, Montana

Date in January	12	13	14	15	16	17	18	19	20	21	22	23
Maximum	25	20	18	27	26	22	14	6	-14	33	35	36
Minimum	0	-4	-14	-11	0	8	3	-23	-44	-34	14	18

The nearest temperature record was at Wisdom, Montana, 27 miles west of the Wise River area. The samples were taken at an elevation of 7,800 feet, while Wisdom is but 6,230 feet. The two areas are separated by the Wise River Valley and a high mountain ridge, which with the difference in elevation and exposure make the possibility of the temperatures being representative of the area sampled rather remote.

Measurement of Existing Temperatures

Continuous hours of temperature below	$0^{\circ}F$	42
Total number of above hours below	$-10^{\circ}F$	37
" " " " " "	$-20^{\circ}F$	27
" " " " " "	$-30^{\circ}F$	12
" " " " " "	$-40^{\circ}F$	2
Temperature measurement - - - - - - - - - - - - - -		120

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree	5' Above Ground						
Side of tree	Total brood per sq.ft.	Percent of mortality	Total brood per sq.ft.	Percent of mortality	Percent of mortality for different bark thicknesses		
					.10-.20	.21-.30	.31-.40
N	56.5	19.7	46.6	59.0	55.2	100	- -
S	81.4	36.9	38.5	74.2			
Conditions in Whitebark Pine							
N	49.2	27.6	103.3	39.2	47.7	54.2	- -
S	52.2	31.9	113.4	57.2			

GARDINER, MONTANA

Temperatures at Mammoth Hot Springs

Date in January	17	18	19	20	21	22
Maximum	23	2	-16	-5	16	26
Minimum	2	-16	-30	-34	-10	16

Temperature records were taken from Mammoth Hot Springs which is about 5 miles southwest of the area sampled. The samples were taken at an elevation of approximately 6,780 feet, while Mammoth is but 6,200 feet.

Measurement of Existing Temperatures

Continuous hours of temperature below	0°F	65
Total number of above hours below	-10°F	41
" " " " " "	-20°F	22
" " " " " "	-30°F	4
" " " " " "	-40°F	0
Temperature measurement - - - - - - - - -		132

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree	5' Above Ground						
Side of tree	Total brood per sq.ft.	Percent brood mortality	Total brood per sq.ft.	Percent of mortality	Percent of mortality for different bark thicknesses		
					.10-.20	.21-.30	.31-.40
N	45.9	9.4	65.2	24	38.5	25.5	- - -
S	31.7	36.8	39.1	55.0			
Status in Whitebark Pine							
N	19.3	24.9	151.0	19.0	13.1	22.2	- - -
S	12.9	61.4	74.4	11.2			

HUTCHINS, MONTANA

Temperatures at Virginia City

Date in January	17	18	19	20	21	
Maximum	18	-6	-22	-30	10	Thirty-one miles northwest of Hutchins and at elevation of 5,822 feet. High ridge between.
Minimum	10	-10	-26	-30	-15	

Temperatures at Ennis, Montana

Date in January	17	18	19	20	21	
Maximum	29	-10	-19	-14	23	Thirty miles north of Hutchins on same river and at 5,000 foot elevation compared to 6,600 to 6,900 for area sampled.
Minimum	-10	-19	-30	-37	-15	

The average of the temperatures recorded for Virginia City and Ennis were taken as best representing conditions for this area.

Measurement of Existing Temperatures

	Virginia City	Ennis
Continuous hours of temperature below 0°F	83	81
Total number of above hours below -10°F	62	76
" " " " " " -20°F	47	36
" " " " " " -30°F	9	0
" " " " " " -40°F	0	0
	201	202

Temperature measurement - - - - - - - - - - - - 201.5

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree			5' Above Ground			
Side of tree	Total brood per sq.ft.	Percent of mortality	Total brood per sq.ft.	Percent of mortality	Percent of mortality for different bark thicknesses	
					.10-20	.21-30 / .31-40
N	51.6	39.7	59.7	58.0	58.3	91.2 / - -
S	43.7	35.2	61.0	70.0		

TOBACCO ROOT MOUNTAINS, MONTANA

Temperatures at Virginia City, Montana

Date in January	17	18	19	20	21
Maximum	18	-6	-22	-30	10
Minimum	10	-10	-26	-30	-15

The area sampled is 10 miles north and some 2,500 feet higher than Virginia City where the temperature records were taken.

Measurement of Existing Temperatures

Continuous hours of temperature below	0°F	83
Total number of above hours below	-10°F	62
" " " " " "	-20°F	47
" " " " " "	-30°F	9
" " " " " "	-40°F	0
Temperature measurement - - - - - - - - - - -		201

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree			5' Above Ground			
Side of tree	Total brood per sq.ft.	Percent of mortality	Total brood per sq.ft.	Percent of mor-tality	Percent of mortality for different bark thicknesses .10-20	.21-30	.31-40
N	66.4	41.5	85.4	77.5	57.7	63.6	82.2
S	56.6	91.0	166.0	56.0			
Conditions in Whitebark Pine							
E	64.6	31.3	72.0	33.3	46.8	47.1	- - -
W	27.0	47.8	53.5	58.6			

CHERRY CREEK, MONTANA

Temperatures at Ennis, Montana

Date in January	17	18	19	20	21
Maximum	29	-10	-19	-14	23
Minimum	-10	-19	-30	-37	-15

Though 15 miles southwest of the Cherry Creek Area, the temperature records at Ennis, Montana were used as being the most representative available. The samples were taken at an elevation varying from 6,800 to 7,250 feet, which is from 1,800 to 2,250 higher than Ennis.

Measurement of Existing Temperatures

Continuous hours of temperature below	$0^{\circ}F$	81
Total number of above hours below	$-10^{\circ}F$	76
" " " " " "	$-20^{\circ}F$	36
" " " " " "	$-30^{\circ}F$	9
" " " " " "	$-40^{\circ}F$	0
Temperature measurement - - - - - - - - - - -		202

MORTALITY OF OVERWINTERING BROOD OF MOUNTAIN PINE BEETLE IN LODGEPOLE PINE AS INDICATED FROM SAMPLES EXAMINED IN FEBRUARY 1935

Base of tree			5' Above Ground					
Side of tree	Total brood per sq.ft.	Percent of mortality	Total brood per sq.ft.	Percent of mortality	Percent of mortality for different bark thicknesses			
					.10-.20	.21-.30	.31-.40	
N	45.2	66.4	37.1	58.2	83.8	89.5	- -	
S	36.4	50.8	25.1	60.1				

The preceding tables show that the Hutchins, Cherry Creek, and Tobacco Root Mountain units were subjected to the greatest number of continuous hours of temperature below zero. These three areas are grouped together into what would appear to be a well defined low-temperature area, which centered rather definitely over Virginia City and Ennis. Very low maximum temperatures of -6°, -22°, and -30° were recorded at Virginia City on the 18th, 19th, and 20th of January, with similar conditions at Ennis, with maximums of -10°, -19°, and -14° for the same dates. Though below-zero, maximum temperatures are not extremely unusual for these areas, such continuous low temperatures as recorded above are considered as abnormal. The temperature allocated to the Hutchins unit is an average of the data from Virginia City and Ennis. In a preliminary analysis of these data the temperature records from Hebgen Dam were used with these two readings. However, as unofficial but checked temperature data at Hutchins were very close to those of Virginia City, it is assumed that this unit was within the low-temperature area, and that the Hebgen Dam temperatures were higher and of shorter duration.

COMPARISON OF TEMPERATURE AND RESULTING BROOD MORTALITY IN LODGEPOLE PINE

Area	Temperature Measurement*	Percent of Brood Mortality at 5 ft. N. Side	S. Side	Average for tree
Ashton, Idaho	43	9.3	5.9	7.3
Jackson Hole, Wyo.	47	16.6	10	13.2
Wise River, Mont.	120	59.0	74	65.9
Gardiner, Mont.	132	23.6	55.2	35.5
Tobacco Root, Mont.	201	80.1	55.6	53.0
Hutchins, Mont.**	201½	57.9	70	64.0
Cherry Creek, Mont.	202	88.1	80	84.9

*The temperature measurement is explained on page 3 of this report.

**This figure is the average of the temperatures recorded at Virginia City and Ennis.

From the preceding table one will note that, regardless of the uncertainty of the temperature readings allocated to the different localities, there is a definite correlation between the measure of temperature and the percent of brood mortality. The only variation to this correlation is the Wise River area, where it is fully recognized that the temperature data are no doubt considerably in error. As previously stated, the temperature allocated to this area was secured from the Weather Bureau station at Wisdom, Montana. This station is some 27 miles southeast and 1,400 feet lower than the area where the samples were taken. It also represents an entirely different topographical condition, being located in a large open basin (Big Hole), while the samples were taken from a heavily timbered mountain region. Furthermore, the Wise River

unit was some 27 miles closer to the Virginia City low-temperature area than Wisdom, Montana. Therefore, we believe that the actual temperatures at Pine River were no doubt lower and of longer duration than those shown by the Wisdom station.

The lack of a definite relationship in the difference in mortality for the north and south sides of the trees is somewhat difficult to explain. Such factors as exposure, sunshine, wind, etc., may have all played a part in causing this variation for the different areas. Furthermore, though one assumes that the mortality would be less on the south side, this assumption is perhaps of little value when the temperature drops below a lethal border line. The variations in temperature recorded at the different Weather Bureau stations indicate the uncertainty of the data assigned to the different units where the samples were secured. Though the Weather Bureau stations show the temperature at a definite location, such data can not be taken as representing conditions within an area a few miles distant.

The trees selected for study were sampled at the base and at a height of five feet for the purpose of comparing conditions below and above the snow. This comparison proved to be of no value, as not all of the trees had a basal protection of snow at the time the samples were taken. Furthermore, in instances where the sample was taken from below the snow there was no assurance that such protection existed during the period of low temperatures. It was therefore subsequently determined that the taking of these basal samples was a wasted effort. However, in Jackson Hole it was rather safely assumed that the base of

the trees was protected by snow at the time of the low temperatures, and the data for this area are presented in the following table:

COMPARISON OF BROOD DATA TAKEN FROM THE BASE AND AT A HEIGHT OF FIVE FEET ON INFESTED LODGEPOLE PINE, JACKSON HOLE, WYO.

	No. of insects per sq. ft. of bark surface	Percent living	Percent dead
Under snow at base of tree	92	57	43
Above snow at five feet above base	104	87	13

In securing basal samples which were below the snow during the low-temperature period, it was assumed that the snow would afford some protection from the cold. Following the low temperatures of 1932-33 the only living brood which could be found in the affected areas was in the basal portion of the trees, and it was assumed that this portion of the tree had been protected by snow. However, the data secured from the Jackson Hole area indicate an opposite condition that we are unable to explain. It is true that the actual temperatures in this area were not of sufficient severity to produce any abnormal mortality above the snow, and it is possible that the snow might have acted as a storage of low temperatures, thus exposing that portion of the tree to a longer continuous below-zero temperature.

In the preceding tabulations shown on pages 5 through 11, no correlation existed between the percent of brood mortality and the different degrees of bark thickness. Though bark thickness is undoubtedly a factor in retarding the occurrence of lethal temperatures beneath, there

are so many other factors involved that a proper evaluation seems to be impossible.

Regardless of the uncertainty of the temperature records, as well as the brood mortality data, there is a marked correlation between the two sets of data. It is recognized that the volume of brood mortality data was not adequate to permit positive conclusions, and it is also possible that a few mistakes were made in the determination of living and dead larvae. Regardless of these possible errors, a correlation exists which can be taken as a rather positive indication that continuous below-zero temperatures result in an increased brood mortality which increases with the severity and duration of the cold spell.

There are questions which can be raised in regard to the relationship between low temperatures and brood mortality that we are unable to answer at this time. The most pertinent of these questions and the one which gave us the most concern at the time this project was instituted, is the relative importance of the recorded brood mortality. Do the dead larvae represent an abnormal mortality, or are they a part of the normal loss which is estimated to be approximately 92% of the potential? With the exception of Cherry Creek, there still remained more living brood per square foot of bark surface than was required for a normal emergence. It was known that additional brood mortality would occur in all of the areas, but it was not known as to what extent it would deplete the surviving brood. To answer this important question the trees from which the samples were secured were reexamined in June 1935, just prior to the emergence

of the insects.

The results of these examinations are shown in the following tabulation:

A TABULATION DEPICTING THE EFFECTS OF THE LOW TEMPERATURES OF JANUARY 1935 ON OVERWINTERING BROODS OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

Brood Data are given as per square foot of bark surface and are the average of samples from the N. and S. sides of the tree at 5 feet.	Ashton, Idaho	Jackson Hole, Wyoming	Gardiner, Mont.	Mont. Root Nts.	Tobacco	Hutchins, Mont.	Rise, Mont.	Cherry Creek, Mont.
A-Temperature Measurement (Page 3)	43	47	132	201		201.5	120	202
B-January brood at time of freeze. Includes living and dead insects shown by February examination. Data in number of insects.	83.1	103.7	52.1	125.6		60.3	42.5	31.1
C-Percent of January brood (B) killed by January temperature.	7.3	13.2	35.5	63.0		64.0	65.9	84.9
D-Number of insects which died between the February and June examinations.	41.5	29.6	15.6	40.8		9.6	10.9	3.5
E-Percent of January Brood (B) dead at time of June examination.	57.3	41.6	65.4	95.9		81.6	91.5	96.1
F-Total number of inches of egg gallery per square foot	67.0	100.7	163.4	187.9		78.8	184.9	138.6
G-Potential brood at time of oviposition-previous studies show 5.3 egg per inch of gallery	461	534	866	677		428	979	734
H-Maximum mortality of the potential brood (G) as shown by June examination.	92.5	88.7	97.9	99.2		97.4	99.6	99.8
I-Number of living insects at time of June examination	34.5	60.5	18.0	5.6		11.1	3.6	1.2
J-Number of 1934 attacks per square foot of bark surface	9.5	9.6	17.0	12.0		7.9	23.2	16.2
K-Percent of increase or decrease in the number of females emerging in 1935 as compared to the number attacking in 1934.	+81.0	+215.1	-47.0	-76.6		-29.7	-92.2	-96.2

The purpose of the preceding tabulation, which has been made rather complete is to show the part which the January temperatures played in reducing the emergence of overwintering broods of the mountain pine beetle in lodgepole pine. It is realized that there are some variations in the tabulation which would perhaps have been eliminated by more accurate temperature records and brood data from a larger number of trees. This lack of data is quite evident in the Ashton area, where on the few trees sampled the remaining brood on the south sides was practically all destroyed by woodpeckers during May and June. Had these factors been eliminated or absorbed by a larger volume of data in order to present a more normal June condition, the maximum mortality (H) would have been lower, with a greater increase of emerging insects over those attacking in the previous season (K). However, it is believed that the conclusions drawn can be taken as an indication of the results that can be expected from future weather conditions of this nature.

The status of the overwintering brood at the time of the January freeze is shown in Section "A". The percentage of the January brood destroyed by the low temperatures is shown under "C". An additional mortality in the remaining number of insects varying from 3.5 insects to as many as 41.5 (D) occurred between the February and June examinations. The total mortality of the January brood (B), secured from a comparison with the living June brood, is shown in Section "E". It will be noted that there is a rather distinct correlation between these

data and the temperature measurements, though discrepancies exist which naturally occur with such a small amount of data. Though these loss figures appear high, there are only two instances (Tobacco Root and Cherry Creek) where they are above a normal mortality of 92 percent, which does not place a very high value upon the effects of low temperatures. However, the full value is not represented, as this mortality was directed against only a very small portion of the total brood. A high brood mortality occurs during the early stages of bark-beetle development, which comprises a large percent of the so-called mortality. Subsequent mortalities are necessarily directed against the residual brood, most of which would otherwise complete its development and emergence. To properly evaluate such abnormal brood destruction as caused by the January temperatures, it was necessary to separate its effects from those that are considered as normal. To secure such an evaluation it became necessary to determine the brood mortality prior to the January temperatures. As oviposition represents the maximum potential brood, the number of eggs was secured by multiplying the length of egg gallery by 5.3 which is the average number per inch of gallery as determined from previous studies. These data are but averages and can not be considered as representing extreme cases. However, the figures are believed to be sufficiently accurate for the purpose of this report.

Sections "F" and "G" show the inches of egg gallery per square foot of surface, with the computed number of eggs. A comparison of the

total brood at the time of the January freeze (B) to the maximum potential brood (G) will show that during this period the loss approached, and in some instances exceeded, the normal mortality. The brood mortality during this period is as follows: Ashton, 86.6%, Jackson Hole, 80.5%, Gardiner, 93.0%, Tobacco Roots, 81.4%, Hutchins, 85.7%, Wise River, 95.6%, and Cherry Creek, 95.7%. This information shows rather clearly the potential value of additional mortality upon the residual brood. Section "H" shows the mortality secured by a comparison of the maximum brood potential (G) and the living insects at the time of the June examination. These data, which are in very close correlation with the temperature measurements, are, with the exception of Ashton and Jackson Hole, above the so-called normal mortality of 92 percent. As a result one may conclude that the brood destroyed by the January temperatures, though only a small percent of the maximum potential brood, was sufficient to raise the total mortality above a normal status. This position is rather clearly demonstrated by the brood mortality recorded for Ashton and Jackson Hole, where the temperatures were mild, and the resulting mortality rather negligible and perhaps not above normal. Though the final mortality recorded for Ashton was slightly above normal, it is believed that the data secured by the June examination were so disturbed by other factors that they were not truly representative.

A further check upon this condition is shown in Sections "I" and "J", where the number of attacks per square foot has been compared to the number of living insects at the time of the June examination. Each

attack was considered as representing one female in 1934, and as our studies have shown that the sex ratio of emerging brood is equal, half of the living brood at the time of the June examination provided an apt comparison between the number of insects attacking and the number emerging. Here again the data (Section "E") show a decrease for all areas except Ashton and Jackson Hole, where very little, if any, abnormal mortality occurred, and where the maximum brood mortality (Section "B") was very close to normal. These data also show a close relationship to both the temperature measurements (A), the low temperature mortality (C), and the maximum mortality (H). Permanent check strips on three of the areas show the following changes in the status of the infestation as occurred in the field: Ashton + 16, Wise River, -92.3, and Tobacco Root -24.5. Though these data support the conclusion drawn from the tabulation, an exactness can not be expected owing to the many confusing factors involved in such analyses.

In conclusion one can rather safely assume that low temperatures which reach a reading of 100 or more (See page 3), and which are subsequent to the early developmental mortality, result in an abnormal destruction of the overwintering broods of the mountain pine beetle in lodgepole pine and cause a natural reduction in the final emergence which increases in proportion to the severity of the temperature.

CONCLUSIONS

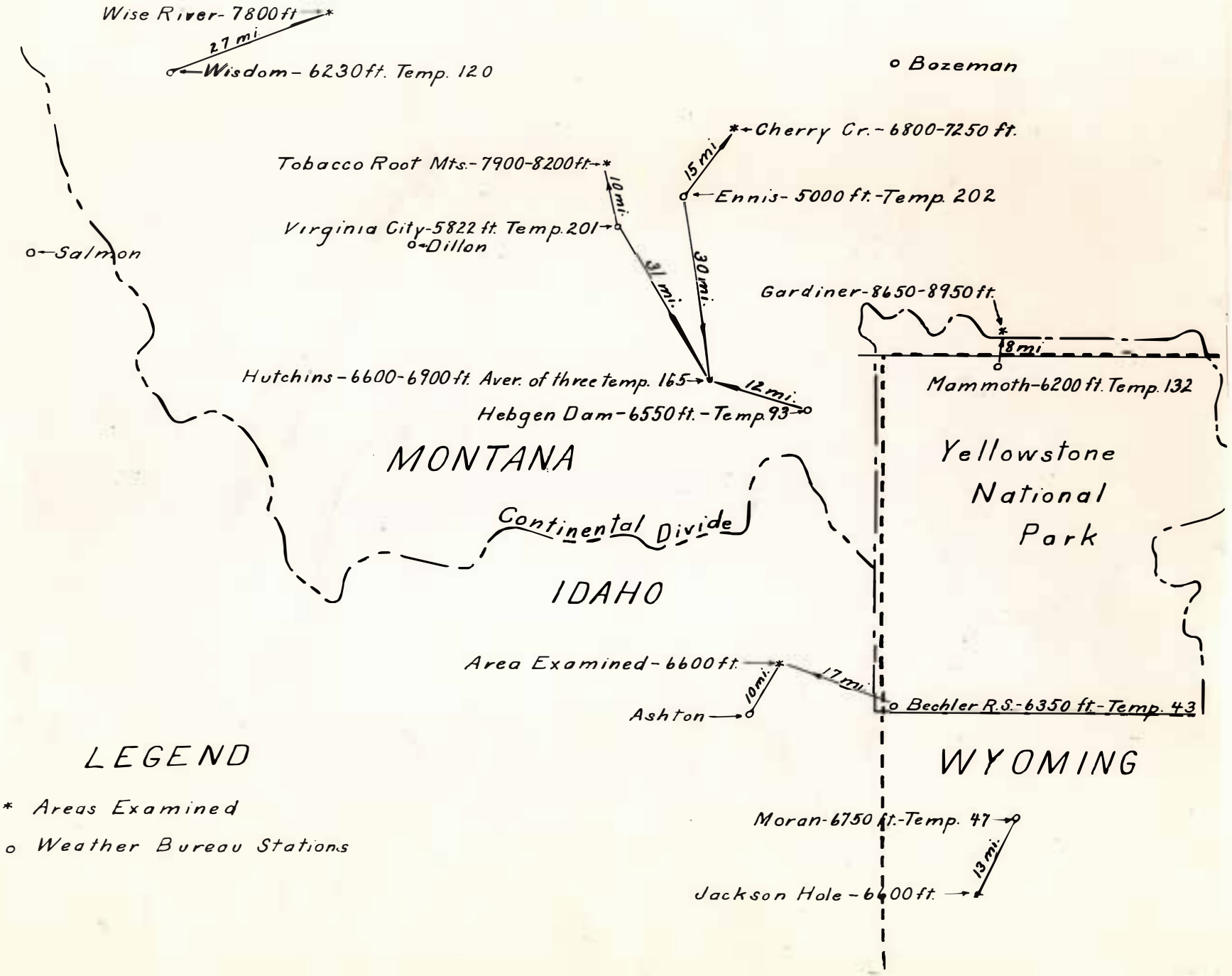
There are many recognized weaknesses in the preceding data upon which we must have more positive information if full advantage is to be taken of the effects which such abnormally low temperatures have upon overwintering bark-beetle broods. Some of these questions will require detailed laboratory study, while the explanation of others rests in additional and more complete field data. Some of the most important items follow:

1. Securing of temperature records that accurately depict existing conditions within the areas being studied.
2. A more thoroughly balanced measurement of temperatures. In the method devised for this report, an hour of temperature at -12 was given twice the weight of one at -2, or an hour at -22 three times the weight of one at -2. These weights were allocated with no fundamental basis, and a series of laboratory tests would undoubtedly provide a more scientific evaluation.
3. Determination of the point in the temperature measurement where mortality starts.
4. Securing of a larger quantity of brood data to eliminate the effects of such discrepancies as shown in the preceding data.

There are many other points which would need be included in a fundamental study of this problem. Both mild and severe winters, all types and characters of infestation, etc., would need be included in such a program if proper evaluations are to be made possible.

Respectfully submitted,

James C. Evenden
Entomologist


Wise River- 7800 ft
27 mi.
Wisdom - 6230 ft. Temp. 120
Bozeman
Cherry Cr. - 6800-7250 ft.
15 mi.
Tobacco Root Mts. - 7900-8200 ft.
10 mi.
Ennis - 5000 ft. - Temp. 202
Virginia City - 5822 ft. Temp. 201
Dillon
Salmon
31 mi.
30 mi.
Gardiner - 8650-8950 ft.
18 mi.
Hutchins - 6600-6900 ft. Aver. of three temp. 165
12 mi.
Mammoth - 6200 ft. Temp. 132
Hebgen Dam - 6550 ft. - Temp. 93
MONTANA
Yellowstone National Park
Continental Divide
IDAHO
Area Examined - 6600 ft.
17 mi.
10 mi.
Ashton
Bechler R.S. - 6350 ft. - Temp. 43
LEGEND
WYOMING
* Areas Examined
Weather Bureau Stations
Moran - 6750 ft. - Temp. 47
13 mi.
Jackson Hole - 6400 ft.